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Future for offshore wind energy in the United Kingdom: The way forward

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ABSTRACT

The majority of our energy demand is satisfied by the combustion of fossil fuels, such as coal, oil and gas. This has resulted in our fossil fuel resources being vastly reduced and has increased the carbon dioxide content in the atmosphere which is causing global warming. The 2020 European Union (EU) targets have been set out to promote the use of renewable technologies and reduce the electricity demand. From the reviewed literature, it was acknowledged that most of these renewable forms of energy sources were initially capital intensive to construct but once constructed they had low operating costs, paying themselves of over their lifecycle. In this study, primary research was undertaken by means of a case study and structured interviews. The case study formed a background to the UK's current and planned offshore wind installations. The results of the interviews were analysed using the NVIVO qualitative software analysis package. This identified themes within the data which allowed them to be analysed and evaluated. The primary data results concluded that the EU targets were challenging but achievable and that the UK government was very supportive in pushing for these targets.

Contents

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1. Introduction

The contribution of offshore wind power to the United Kingdom's (UK) future energy balance is an important area worthy of investigation for a number of reasons. First and foremost, the world has become more industrialised over the years, which has lead to increasing pressure being put on the planet's energy resource of fossil fuels [1,2]. This has resulted in our fossil fuel resources being vastly reduced and has increased the carbon content in the atmosphere. Over the years there have been various frameworks, strategies and legally binding agreements released in relation to combating climate change and achieving security of energy resources i.e. the Kyoto Protocol [3,4]. Today, the UK is still facing the same issues as before with regards to energy security, demand and the environmental damage as a result of increased green house gas emissions [5,6]. Government policies have for a long time recognised the need for a heavy contribution from renewable technologies to generate clean carbon free electricity and to improve energy security.

The European Union [7] set its targets in the *Climate Change and Energy Strategy* for 2020. These included a 20 per cent reduction in greenhouse gases and energy consumption by 2020 against the levels in 1990. The EU has also highlighted the need to increase electricity generated by renewable energy by 20 per cent by 2020 against the levels in 1990 [8]. Wind power has been around since time began and has been used throughout history for various processes. According to the *European Wind Energy Association* [9] the wind energy market has recently been one of the fastest developing renewable energy markets and, over the past decade, moved off shore. Various researchers, such as Freris and Infield [10] suggested that over the next ten years, wind power will contribute the most to electricity production out of all the renewable sources of energy. This has prompted the question, *how will offshore wind power contribute to the United Kingdom's energy balance?*

With the world's fossil fuel energy resources depleting, future prosperity is looking dim at the minute for the United Kingdom. Oil and gas reserves are slowly dwindling away and are no longer sufficient enough to sustain the ever increasing energy demand. Although the North Sea still holds a considerable quantity of both oil and gas it will continue to fall as the economy grows [5,6]. To date, the UK has relied quite significantly on imports of fossil fuels for our energy production. This increasing dependence is no longer practical, as relationships have become more unsteady. The fight for supplies has recently escalated due to them being concentrated in less prosperous areas of the world. This has allowed corrupt systems to be used to try secure sources of fossil fuels which should never have happened and most definitely cannot continue [5,6]. The concentration of greenhouse gases in the atmosphere, due to the exploitation of these fossil fuels has caused major environmental concerns and the fears of global warming and climate change.

The Department of Energy and Climate Change set out in the Energy White Paper of May 2007 [11], two long-term energy challenges which UK will be facing, which are: tackling climate change by reducing carbon dioxide emissions both within the UK and abroad; and ensuring secure, clean and affordable energy as we become increasingly dependent on imported fuel [11]. This has forced the need to start investing time and money into alternative forms of energy. The high energy prices, climate change and energy security have encouraged governments across the world to seriously tackle this concern [12,13]. This is giving various companies a great opportunity to capitalise on this very lucrative renewable energy market. The increased ventures in this particular field combined with the increased use of renewable energy sources has moved what once was thought of as an alternative energy source, into an increasingly competitive energy source.

As the technological advances in wind, wave, water, solar and geothermal increase so too does the power output of these technologies. Although renewable energy is sometimes criticised for being intermittent this increase in technology and power output is vastly seeing their popularity grow. The surprising turn of events over the past years resulting in the emergence of these options to the traditional reliance of energy supplies from fossil fuels, highlights the significance of other alternative sources of energy supply. This paper therefore focused on how offshore wind power will contribute to maintaining the United Kingdom's energy balance and how it will fit into alternative energy plans that boost electricity generation from carbon neutral technologies. The paper also provides insights on global demand for energy, energy security, conventional energy resources and renewable energy resources. The second part of this paper examined global demand for energy, energy security, conventional energy resources and renewable energy resources.

2. Global demand for energy

Today the vast majority of energy supply needs are met through the burning of fossil fuels such as coal/peat, oil and gas, which fuel our modes of transport, power our industries and light our homes [14–16]. The reliance on fossil fuels has not changed much since 1973 and this can be seen clearly in Fig. 1, which show fossil fuels in 2008 contributing a large 86 per cent to our global energy supply with a mere 13.4 per cent coming from other forms such as combustible renewable, waste and hydro [17].

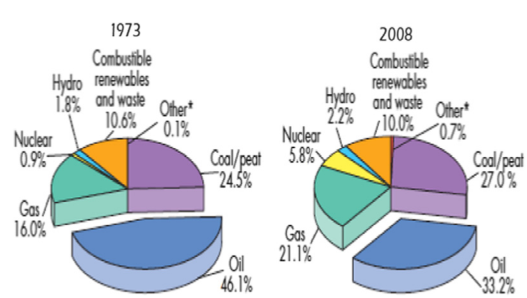


Fig. 1. Global total primary energy supply between 1973 and 2008. *Source*: (17, Key world energy statistics, p. 6).

Global consumption and supply of energy has grown vastly over the past couple of decades, doubling since 1973, from 6115.21 millions of tonnes of oil equivalent (Mtoes) to 12267.38 Mtoes [17]. This is evident in Tables 1 and 2 which also show that, a large proportion of our energy is being imported and exported globally.

Research by Wesley [18] indicated that the global demand for energy is due to grow dramatically over the next two decades with the most rapid increases coming from the United States, China and India. This has also been concluded by the *International Energy Agency* [19], who stated that the world's energy demand will increase by 36 per cent between 2008 and 2035, 1.2 per cent per year on average, which is 0.8 per cent less than over the previous twenty-seven year period. In order for this to happen the International Energy Agency (IEA) assumes that there will need to be cautious implementation of the policy commitments and plans announced by countries around the world, including the national pledges to reduce greenhouse-gas emissions and plans to phase out fossil-fuel subsidies [19].

It is extremely difficult to calculate how long the remaining resources of fossil fuels will last, as the rate of consumption can rapidly change as our planet grows and develops. Researchers at bionomic fuel predict that there is approximately sixty years of oil and one-hundred years of gas remaining. It is clear from these findings that there is the need globally for governments to instigate energy policies, in order to utilise these finite resources adequately [20].

3. The security regarding our energy resources

There is a major issue worldwide regarding the security of finite fossil fuel supply. As previously noted in Fig. 1, oil is the most widely utilised primary energy source closely followed by coal and peat at 33.2 per cent and 27 per cent respectively. A closer observation of Table 3 reveals that, presently, a large percentage of the global crude oil is located in politically unstable regions of the world, such as the Middle East and Russia.

Table 1
Global energy balance from 1973 to 2008.
Source: (17, Key world energy statistics, p.3 6 and 37).

1973 (Mtoe)									
Supply and consumption	**Coal/peat**	**Crude oil**	**Oil products**	**Gas**	**Nuclear**	**Hydro**	**Combustible renewables and waste**	**Other**	**Total**
Production	1479.01	2936.72	–	993.10	53.05	110.23	646.11	6.13	6224.35
Imports	140.04	1562.25	408.21	73.41	–	–	0.12	8.14	2192.16
Exports	−130.37	−1611.16	−438.63	−72.57	–	–	−0.19	−8.27	−2261.20
Stock changes	12.22	−21.58	−15.79	−15.00	–	–	0.06	–	−40.10
TPES	**1500.90**	**2866.21**	**−46.21**	**978.94**	**53.05**	**110.23**	**646.09**	**6.00**	**6115.21**

Table 2
Global energy balance from 1973 to 2008.
Source: (17, Key world energy statistics, p. 36 and 37).

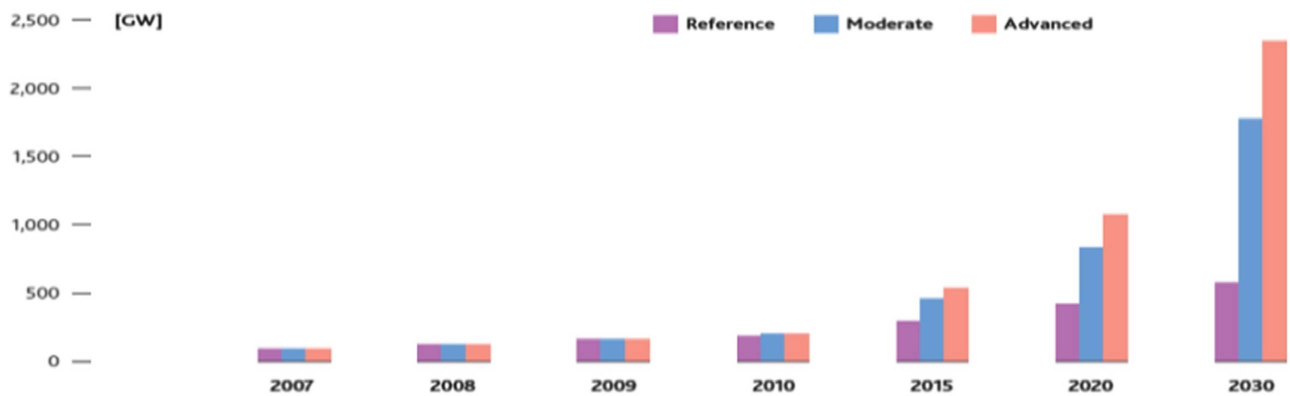
2008 (Mtoe)									
Supply and consumption	**Coal/peat**	**Crude oil**	**Oil products**	**Gas**	**Nuclear**	**Hydro**	**Combustible renewables and waste**	**Other**	**Total**
Production	3415.66	4041.34	–	2608.17	712.18	278.88	1225.49	90.24	12368.95
Imports	591.76	2332.71	995.62	782.77	–	–	8.49	52.84	4764.20
Exports	−631.03	−2200.43	−1074.56	−777.77	–	–	−9.32	−53.00	−4746.11
Stock changes	−62.21	−28.78	−6.72	−22.10	–	–	−0.15	–	−119.66
TPES	**3314.18**	**4144.84**	**−85.65**	**2591.07**	**712.18**	**275.88**	**1224.81**	**90.08**	**12267.38**

Table 3
Producers, net exporters and net importers of crude oil.
Source: (17, Key world energy statistics, p. 11).

Producers	**Million ton (Mt)**	**Percentage of world total**	**Net exporters**	**Million ton (Mt)**	**Net importers**	**Million ton (Mt)**
Russian Federation	494	12.9	Saudi Arabia	355	United States	564
Saudi Arabia	452	11.8	Russian Federation	241	Japan	199
United States	320	8.3	Islamic Rep. of Iran	120	People's Rep. of China	175
Islamic Rep. of Iran	206	5.4	United Arab Emirates	108	India	128
Peoples Rep. of China	194	5.0	Nigeria	102	Korea	116
Canada	152	4.0	Angola	92	Germany	105
Mexico	146	3.8	Norway	90	Italy	88
Venezuela	126	3.3	Kuwait	89	France	83
Kuwait	124	3.2	Iraq	88	Spain	61
United Arab Emirates	120	3.1	Venezuela	74	Netherlands	57
Rest of the world	1509	39.2	Others	593	Others	514
World	**3843**	**100.0**	**Total**	**1952**	**Total**	**514**

Table 4
Producers, net exporters and net importers of natural gas.
Source: (17, Key world energy statistics, p. 13).

Producers	Billion cubic metres (Bcm)	Percentage of world total	Net exporters	Billion cubic metres (Bcm)	Net importers	Billion cubic metres (Bcm)
United States	594	19.2	Russian Federation	160	Japan	93
Russian Federation	589	19.0	Norway	100	Germany	83
Canada	159	5.1	Canada	76	United States	76
Islamic Rep. of Iran	144	4.6	Qatar	67	Italy	69
Norway	106	3.4	Algeria	55	France	45
Peoples Rep. of China	90	2.9	Indonesia	36	Ukraine	38
Qatar	89	2.9	Netherlands	30	Turkey	35
Algeria	81	2.6	Turkmenistan	27	Spain	34
Netherlands	79	2.5	Malaysia	24	Korea	33
Indonesia	76	2.5	Trinidad and Tobago	21	United Kingdom	29
Rest of the world	1094	35.3	Others	140	Others	214
World	**3101**	**100.0**	**Total**	**736**	**Total**	**749**



		2007	2008	2009	2010	2015	2020	2030
Reference	[MW]	93,864	120,297	158,505	185,258	295,783	415,433	572,733
	[TWh]	206	263	347	406	725	1,019	1,405
Moderate	[MW]	93,864	120,297	158,505	198,717	460,364	832,251	1,777,550
	[TWh]	206	263	347	435	1,129	2,041	4,360
Advanced	[MW]	93,864	120,297	158,505	201,657	533,233	1,071,415	2,341,984
	[TWh]	206	263	347	442	1,308	2,628	5,429

Fig. 2. The world's cumulative wind power capacity (2007–2030).
Source: (35 GWEC and Greenpeace International, p. 6).

What this implies is that the longevity of energy supply is uncertain with the current ongoing conflict which exists between our western and Islamic cultures [17]. This problem of energy security was very evident in January 2009 when, due to tensions over gas supplies Russia cut gas to Ukraine for a fortnight [21]. Due to Russia being one of the largest producers and exporters of gas to the European Union (EU), as seen in Table 4, this event has made EU member states realise how dependable they are on this single source of energy.

According to Wesley [18], this increasing dependency of the world on supplies from unstable regions means that the adequate supply of affordable energy will become increasingly a part of most states' security calculations in the coming decades.

4. Global action

In June 1992 most countries joined an international treaty called the United Nations Framework Convention on Climate Change [4]. The objective of these conventions was to stabilise the green house gas concentrations in the atmosphere, with the overall aim to prevent further hazardous anthropogenic interference within our climate. The Kyoto Protocol was adopted in Kyoto. According to UN [4], this treaty was an international and legally binding agreement to reduce greenhouse gas emissions worldwide. It sets legally binding targets for thirty-seven industrialised countries and the European community to reduce their greenhouse gas emissions, by an average of 5 per cent against 1990 levels during the period of 2008 to 2012.

In 1991 the European commission [22] issued a community strategy to improve our energy efficiency and put limits on our carbon dioxide emissions, with the aim of promoting the electricity generation from renewable sources. The European Union then launched the European Climate Change Programme (ECCP), which was established in 2000. This programme required EU-fifteen members to work together to reduce their combined emissions by 8 per cent below the 1990 base level by 2012. The Climate Change and Energy Strategy assembled by the EU was commissioned in March 2007 [22]. The aim was to achieve a 20 per cent reduction in greenhouse gases below the 1990 base level,

cut energy consumption by 20 per cent and increase the use of renewable's to 20 per cent of the total energy production by 2020.

It is worth highlighting that the "*Low Carbon Transition Plan*" of July 2009 and the "*White Paper on Energy*" of May 2007 are the most recent energy policies that have been set out for the United Kingdom. They have been built on the previous "*Energy Review Report*" of 2006 and the "*Energy White Paper*" of 2003. As intimated earlier, the White Paper of 2007 identified the two long term energy challenges that the UK will be facing as:

- Tackling climate change by reducing carbon dioxide emissions both within the UK and abroad; and
- Ensuring secure, clean and affordable energy as we become increasingly dependent on imported fuel [11].

The Climate Change Bill was enacted by Royal assent and became the Climate Change Act [23]. The Department of Trade and Industry concluded that this made the UK the first country in the world to have a legally binding long-term framework to cut carbon emissions [23]. The Department of Energy and Climate Change (DECC) [24] stated that the CCA committed the UK to reduce its carbon emissions by 26 per cent below the 1990 baseline by 2020 and to reduce green house gas emissions to at least 80 per cent below the 1990 baseline by 2050. According to the Department of Energy and Climate Change [25] in 2009 the UK greenhouse gas emissions were 8.7 per cent lower than in 2008 and approximately 18 per cent lower than 1990. The recession that the UK has currently witnessed has resulted in a reduced overall demand for electricity. This has recently helped in reducing emissions, but will soon rise again when the recession passes. The DECC [26–28] has claimed that the decrease in emissions has resulted from an increase in the use of nuclear power for electricity generation instead of coal and natural gas, which is not renewable.

The UK Renewable Energy Strategy carries on from the UK's commitment to the EU renewable energy directive, and considers the implications of all previous policies and existing legislation regarding climate change and energy, for the United Kingdom to produce 15 per cent of its energy from renewables by 2020 [26]. According to the Secretary of State for Energy and Climate Change, this target was the equivalent to a seven-fold increase in UK renewables from about 2.25 per cent in 2008 [28]. It is evident that the UK needs to push further into the renewable energy market in order to obtain a secure supply of electricity and to transform the UK in to a low carbon economy.

5. Conventional energy resources and renewable energy resources

Chauhan (2007) regarded conventional sources of energy as the population's fossil fuels (coal, petroleum and natural gas) and nuclear energy. Over the last twenty years the thermal conversion of gas power stations has improved significantly, with the development of combined cycle gas and steam turbines now reaching a net efficiency of 58 per cent [10,29]. The IEA [19] has forecast a long-term upward trajectory from 2010, with demand increases of 44 per cent between 2008 and 2035, surpassing that of other fossil fuels due to its more favourable environmental and practical attributes.

Nuclear fusion is in no way a conventional energy source, it is the power that fuels the sun and the stars [30]. It is worth mentioning, as significant research and development has been directed toward this field of energy production, such as the International Thermonuclear Experimental Reactor at Cadarache in France [31]. The Culham Centre for Fusion Energy suggests fusion could contribute heavily to our carbon-free energy future [31]. Although Dolores et al. [32] have highlighted a lack of progression regarding fusion with other sources suggesting the technology may never be financially viable or cost effective [10].

There are a variety of different energy paths that can be utilised to produce renewable electricity. The primary source for creating these renewable energy flows is the sun. Breeze [15] has acknowledged that most renewable technologies are capital intensive but have low operating costs, while fossil fuels are usually cheaper to construct but much more expensive to operate over time. Conventional technologies currently have their primary energy source readily available. The same can be said for renewables such as tidal biomass and hydro but the availability of wind, wave and solar is not always predictable and varies. Renewable technologies have been criticised for not being able to contribute as much power as conventional coal and gas connected to the grid [33].

Many of these renewables cannot be economically justified going through the grid, but they can be justified in the long run when used as standalone system. They can be mounted on roofs or building facades to meet the energy demands of particular consumers, allowing surplus to be sold back to the grid. According to Skoglund et al. [34], intermittent power is a large obstacle for renewable electric energy conversion systems and often does not coincide in time with the user's energy demands. Hydropower is the only renewable that can quickly match consumer demand granted there is a head of water behind the gates.

6. Growth of global wind sector

According to figures released by the Global Wind Energy Council [35], global wind installations have grown by 35.8 GW in 2010, bringing the total installed capacity up to 194.4 GW. The GWEC [36] have claimed that this is a 22.5 per cent increase on the 158.7 GW installed at the end of 2009 (GWEC, 2011). This increase in installed capacity can be seen in Fig. 2 below. The GWEC [35] concluded that their referenced scenario suggests growth rates start at 17 per cent in 2010 and then drop to stabilise at 3 per cent by 2015.

The pace of wind energy deployment within the UK has continued to accelerate through 2010, with the UK reaching an installed capacity of over 5 GW. This is enough to power all the homes in Scotland [37]. This was made possible with the commissioning of Thanet, which now holds the title of the world's largest offshore wind farm. Beament [37] claims the Thanet wind farm off the coast Kent will produce enough electricity to supply the equivalent of more than 200,000 homes a year. The UK has been very slow to embrace wind developments on a large scale taking just over 13 years to reach an installed wind capacity of 1 GW in 2005. According to Renewable UK [38] it only took twenty months to achieve the second and third GW, with the fourth closely following twelve month later in October 2009.

7. Offshore wind powers drivers and drawbacks

Offshore and onshore have a range of benefits and drawbacks, with sources such as Breton et al. [20] arguing that offshore wind energy has much more advantages than its onshore counterpart, as onshore installation sites are becoming increasingly scarce compared to the vast range of available offshore sites. As the sites are off the coast, the visual impact and noise emissions can almost be eliminated. Another major benefit of offshore, concluded by Mostafaeipour [39] is the point that the winds offshore are generally stronger, more uniform, with less turbulence. According to Breton et al. [20] this may enable increased productivity, which

could offset higher installation and operating costs. The overall turbine units and blades are larger, thus achieving more power per unit, as there is virtually no size restrains as transportation and erection are completed at sea.

Offshore wind units according to Zhixin, et al. [40] are double or triple the cost of their onshore counterparts. Dolores et al. [32] explain that the high costs are mainly due to the sea operations. The turbines must also be prepared for the corrosives conditions in the air and roughness of the sea, meaning special purpose air condition systems are essential for the nacelle. Connecting wind turbines to existing systems can mean savings in operating costs as less fuel will be consumed by conventional technologies. Although there are many technical problems when integrating wind plants with existing electricity systems, new lines and substations may need to be constructed to connect to existing system if the suitable network is not near the turbine. Opposition from the public can derail most developments but Wolsink [41] found that the attitude of the public was not the issue, as the general attitude towards wind power was very positive. Sesto and Casale [42] also found that the public reaction to wind turbines is generally favourable, when compared to other generating technologies, but opposition arises when turbines are in densely populated areas. However, familiarity with the technology and the revenue producing potential subsequently helped to improve public acceptance [42]. Jones and Eiser [33] found that in general terms, when the development is out of sight it is deem relatively acceptable which is positive for offshore wind power. The next section details the research method and a symposium of findings drawn from discussions with senior practitioners and government policy makers.

8. Method

Due to the nature of the research aim, it was acknowledged that the views of senior practitioners in the offshore wind sector were necessary. This allowed questions evoked from the initial research to be answered and contribute additional information to give a better understanding as to how offshore wind power would contribute to the United Kingdom's energy balance. The use of a qualitative method was deemed to be the most appropriate research strategy to employ. The use of a quantitative approach was unsuitable as there was no hypothesis to commend or reject due to the dynamic nature of the renewable energies sector the technology deployed constantly evolves, thus implying that a considerable amount of current information has not yet been released. This study therefore focused on evoking further, more current information from participants and to gauge their opinions on questions of an explorative nature. A statistical hypothetical approach was not suitable for this type of data as the data was in the form of different senior practitioner's views and interpretations.

A qualitative method of data collection was adopted by means of interviews paired with a recent case study. The interviews were set in structured format, with predetermined questions with the same wording and order, so that the same circumstances would apply for each participant. The interview questions were cautiously selected in an attempt to prevent any preconceived bias. It was assumed by Nachmias and Nachmias [43] that the interviewees would have a sufficiently common vocabulary, so the constructed questions would have the same meaning for each of them and that it would be possible to phrase the questions in a format that is meaningful to each candidate. Through using interviews there was the opportunity to network with the participants and explore further into their opinions that they wished to share and to protract a more in-depth response, compared to questionnaires which allow for a limited response.

The open ended interview questions allowed additional information to be gathered and further reasoning behind responses to be explored, this allowed for a better understanding behind the participants thinking. As previously mentioned views and perceptions of professionals in the offshore wind sector were required to answer questions evoked from the initial research and to gauge a fuller picture of the current industry. The professionals were carefully chosen, to accurately represent the wind power sector. The researchers attended a large national offshore wind supply chain event in Liverpool (UK). This allowed the researchers to network with a range of professions across the spectrums who were involved in the supply chain of renewable technologies and offshore wind. This meant the most appropriate candidates for interview were selected at the event and it acted as a means of increasing the response rate through establishing the initial face to face contact. After the professionals were then chosen and had agreed to participate in the interviews they were handed a hard copy of the finalised interview questions to review to allow them to air any queries they had in relation to the questions. Among the criteria used to identify leading senior practitioners were their abilities to manage energy projects and familiarity with conventional energy resources. A preliminary pilot study was carried out with the practitioners so as to assess clarity of questions. All interviews were recorded to allow for ease of reference and to produce accurate transcripts. As illustrated in Table 5, the professionals selected were public affairs managers for renewable energy, supply chain managers, offshore wind development managers, offshore head directors and senior government policy makers.

For the purposes of confidentiality, the participant's names and the names of their organisations have been changed. These professionals were selected because of their vast knowledge of the wind farm industry and their involvement in the offshore wind developments within the Irish Sea zone, which forms the case study. A "funnel" technique was adopted for the structure of the interviews, which meant more general questions were asked at

Table 5
Selection of professionals interviewed.

Participants	Number of participants	Years of experience	Organisation
Public affair managers for renewable energy	**(5)** A, C, E, J, K	10–20	Energy
Supply chain managers	**(4)** B, D, F, I	10–20	Energy
Offshore wind development managers	**(5)** R, T, O, N, M	10–20	Energy
Offshore head directors	**(3)** G, H, P	10–20	Energy
Senior government policy makers	**(3)** Q, S, L	10–20	Department of Energy and Climate Change (UK)

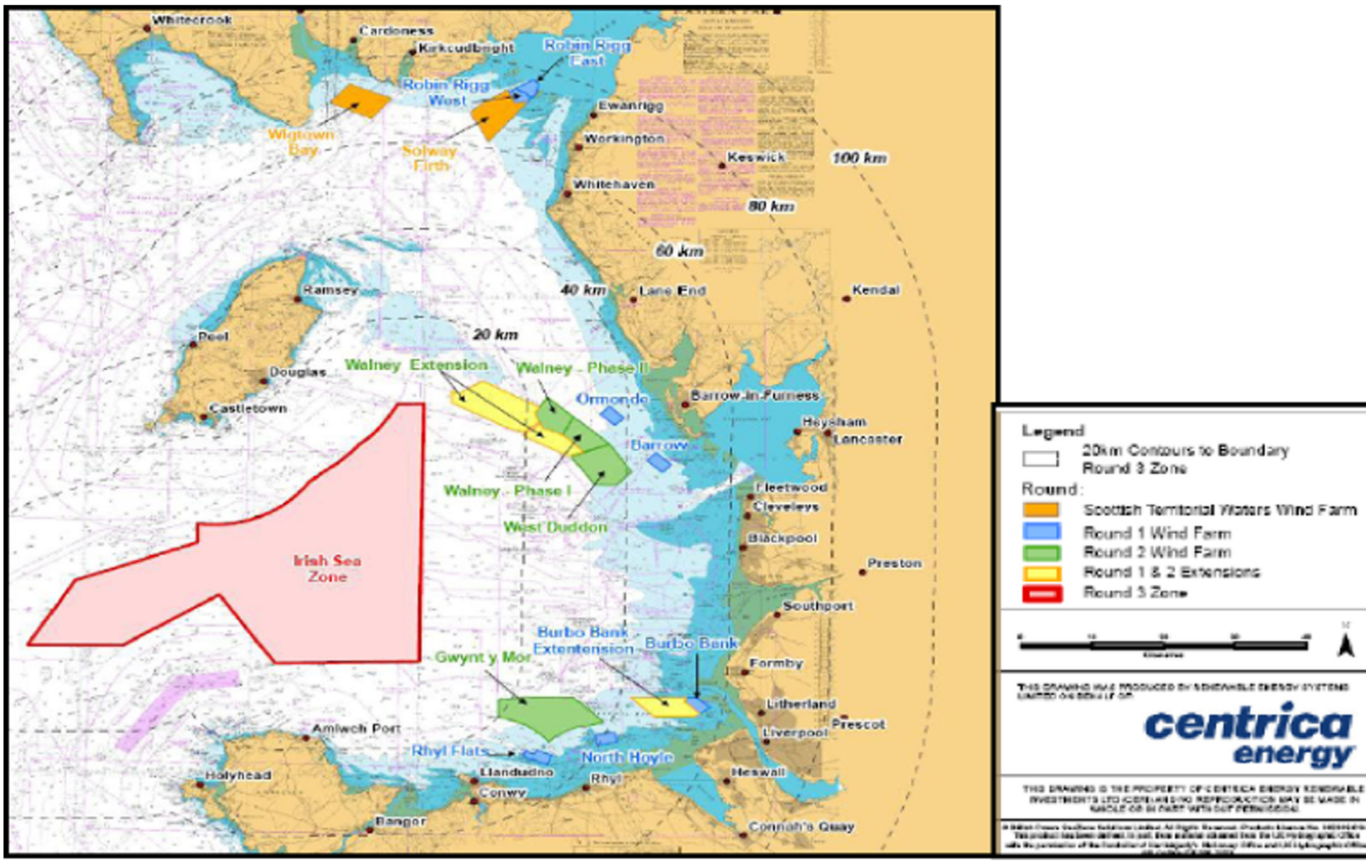


Fig. 3. Map of Irish Sea Zone.
Source: [47].

the start to break the ice, which were easier to answer, followed by more specific questions which required more thought in relation to offshore wind power with focus on the case study. The last question wound down the interview through asking about their personal thoughts of the future of offshore wind. As shown in the appended questionnaire (Appendix. A), the first and second question were asked in order to understand the participants overall opinion on the importance of alternative methods of generating electricity and to gauge their opinion on why they think alternative technology has taken so long to be utilised in the UK, which was a question that arose in prior research. The third and fourth questions were structured to solicit their knowledge on the current energy policies present in the energy sector; ascertain if the interviewed professionals perceive these policies as being achievable for the UK and also if they believe alternative energy fitted into these policies.

The fifth and sixth question attempted to gauge opinion on why it has taken so long for the UK to utilise offshore wind energy despite the vast wind resource present in the region and to ascertain how well offshore wind fitted into the current alternative energy sources available in the UK. The seventh, eighth and ninth question continued to focus on the offshore wind sector but linked in elements of the case study in an attempt to understand if the region of Merseyside (Liverpool, UK) had the potential to become an integral part of the supply chain for the Irish Sea Zone. The potential barriers and driver for the region were examined in depth to understand what the offshore wind sector could present to the Merseyside region. The final question gave the professionals the chance to voice their thoughts on the future of offshore wind in the UK and to close the interview session.

A copious amount of data was produced from the interviews, which needed to be analysed. It was important to choose the most adequate method for data analysis so the information could be interpreted efficiently and effectively. An inductive approach was utilised, according to Braun and Clarke [44] this is where the researcher will try to identify commonality and report themes within the collated data. Boyatzis [45] describes these themes as a pattern within the information that at a minimum will describe and categorises the observations and at a maximum will deduce aspects of the phenomenon. For this thematic analysis it was important to identify a limited amount of themes that would adequately reflect the documented data. Grbich [46] concluded that it was a method of reducing data into meaningful categorises. Boyatazis [45] breaks thematic analysis down further into the phases of seeing (recognising a moment), encoding (seeing it as something) and interpretation.

It was also important that the researchers carried out the interviews themselves in order to familiarise themselves with the data at an early stage, as the first step of analysing qualitative data according to Braun and Clarke [44]. Each transcript was then individually broken down into various initial codes, 1st, 2nd and 3rd level coding. These codes were then analysed for commonality and examined for themes. These themes were then revisited and allocated names, by the end of this stage Braun and Clarke [44] conclude that the researcher should be able to define what the themes are and what they are not. This method of analysing the qualitative data was implemented once the interview transcripts were completed. A computer assisted qualitative data analysis software (CAQDAS) in the form of NVivo was utilised, this allowed the data to be coded efficiently and thus reduced the time period

needed to analysis the copious amount of data collected. The verification took place after the interpretation of data analysis. This involved presenting the findings to the main participants. The philosophical consideration of this research can be viewed from three broad perspectives. The first perspective was linked to the importance of alternative energy. The second perspective was linked to exploring key drivers of offshore wind projects in the UK. The third was linked to examining the future of offshore wind in the UK.

The case study was utilised to build background knowledge on the offshore wind developments within the UK. This evoked further questions for the interviews, which both strengthen and oppose the opinions of prior research and provided a broader understanding in to how to become involved in the offshore wind supply chain. The case was structured using the "funnel" technique, by briefly looking at the various offshore sites released by Crown Estates around the United Kingdom, followed by a more in-depth analysis of the round three Irish Sea Zone as illustrated in Fig. 3. Centrica (2010) has claimed that the site has the potential to generate 4.2 GW of renewable energy, enough to power around 3 million homes per year.

In December 2000, the Crown Estate [48] announced the development of the first round of UK offshore wind farms. This round one sites were to cater for up to 30 turbines with the selection of sites largely driven by developers. For round 2 the UK Department of Trade and Industry [49] proposed a strategic planning frame work for expanding the offshore wind industry and restricted further development to three strategic areas: Greater Wash, Thames Estuary and Northwest (Liverpool bay). There were 15 successful projects, amounting to 7.2 GW of power within these sites and beyond territorial waters. The Crown Estate announced the proposals for the third round of wind farm leasing on the 4th June 2008. On the 8th of January 2010 the Crown State announced the winning bidders for the nine individual offshore wind farms within the Round 3 programme.

9. Findings

All interviews were successfully completed without complications by the professionals previously assessed in the method section. The success of these interviews may perhaps be attributed to the pilot interviews commissioned prior to the final interviews. The main themes identified were:

- Theme 1: Importance of alternative energy.
- Theme 2: Rationale for the UK's 'backwardness' in renewable energy.
- Theme 3: Current government energy policies.
- Theme 4: Alternative energy fitting into UK energy policy.
- Theme 5: Rationale behind why UK is lagging in installed off shore wind capacity.
- Theme 6: Utilisation of offshore wind power to meet UK 2020 targets.
- Theme 7: Rationale behind UK and Merseyside becoming part of the supply chain for offshore wind.
- Theme 8: The Barriers the Irish Sea Zone and Merseyside region face.
- Theme 9: Key drivers for the Irish Sea Zone and Merseyside region.
- Theme 10: Future of offshore wind in the UK.

9.1. Theme 1: Importance of alternative energy

The first main theme which was drawn from the primary data was the importance of alternative energy. All participants strongly stressed how crucially important alternative energy is in this current economic climate, with Participant (B) stating *"it is critical to the future of this country and our EU related targets"*. The main sub themes evolved from this theme were security of supply and decarbonisation. Security of supply was highlighted in NVivo as the most critical of the two sub topics, with participants (C) and (F) outlining the need to have a diverse mix of resources, as renewables are either resource specific or intermittent. Creating this mix of renewable resources also means the UK is not exposed to volatile price spikes with gas and oil price as participant (C) outlined. This school of thought is clearly evident from the previous literature, with Wesley [18] arguing that the adequate supply of affordable energy will become an increasing part of most states security calculations.

The importance of having indigenous means of generating electricity was also acknowledged by participant (G) who also commented that we *"shouldn't preclude importing fuel for electricity providing it is cost effective"*. Although decarbonisation only contributes a small fraction to the discussion it is still of vital importance. Two of the participants (T and S) suggested that carbon reduction as being extremely important; with participant (I) outlining again the importance of climate change as a result of our increase carbon emissions. This supports the aforementioned reports of Goldstein [50] and Cox [3] regarding the anthropogenic leading to climate change.

9.2. Theme 2: Rationale for the UK's 'backwardness' in renewable energy

As noted by the twenty participants, the main reasons behind why the UK was lagging behind in renewable energy was because of their reliance on fossil fuels. Another key issue which has been stressed throughout the literature and primary data was the complexity of the planning system [33,51]. Participant (M) and (N) commented about the fact that *"we have been blessed with coal oil and gas reserves in the North Sea"* with participant (N) concluding that there was no reason to explore other expensive forms of energy with oil and gas reserves on our doorstep. They then go on to explain that recently over the past five years the UK has become an ethics quarter of energy and are looking to catch up. Participant (L) however asserted that fossil fuel reserves *"couldn't really have slowed the UK down in its uptake of renewable as fossil fuels have been around since the mid late 70s onwards"*.

The complexly of the current planning system according to participant (O) has been detrimental in relation to the offshore wind sector and makes it difficult for businesses to invest and therefore not seen as economically viable. This is an area that has not been previously acknowledged in the past research but seems to be one of the main reasons behind why the UK was behind in renewable energy. Participant (H) suggested that the main reason for this delay in the uptake of renewable has been because there was not any sort of financial incentives until recently for companies to combat these high costs and to build new capacity of any sort. As well as this, most of the renewable equipment since the nineties has had to be imported from abroad because the UK has no local manufacturing sector to keep prices competitive.

9.3. Theme 3: Current government energy policies

A range of opinions have been evoked in relation to the government's current energy polices. From the analysis, the sub theme supportive government was the most discussed aspect, contributing to almost half of the discussion, with comments from all participants. Most participants believed that the 2020 energy target set by the EU are achievable. However, Participant (C) believed that the targets that have been set out are achievable

but fears that they will be missed if the incentive resume for renewable obligations is removed. Participant (C) further noted that the targets will not be missed just based on this, but because the UK was late to pick up in the renewables sector, as previously mentioned in theme two. Overall, it has been concluded that the government has been really supportive of renewable energy but has set very challenging targets. However, participant (J) argued that the government has focused too much on electricity generation as a means to reduce carbon emissions which is an easy win for them as it is harder to reduce carbon emissions in the other sectors and improve energy efficiency, but if the government did the energy demand would be considerably lower. A tension in the government surrounding a free market economy was discussed by participant (A), who later concluded it was not the case as the government introduced subsidies and financial support for technology they feel should be deployed.

9.4. Theme 4: Alternative energy fitting into UK energy policy

Within this theme all participants agreed that alternative energy clearly did fit into the UK energy policy, with participant (D) stressing it is a crucial part. Although this theme sparked a range of responses, regarding why alternative energy fitted, each sub-theme came from a different participant. Participant (Q) debated the fact it fits because the government is *"now seriously looking at upgrading grid connections to Europe in terms of being able to trade electricity"* and to resource renewables from where they are best, such as Hydro from Norway, Solar from the Mediterranean etc.

According to participant (S) it fits the policies from an environmental and economic point of view, as it provides "diversity with nuclear, gas, coal and renewable's mainly wind but also provides a vast amount of jobs in renewable energy sector, which is now more than the coal industry". It is key for developing technology such as nuclear, offshore wind and carbon capture and storage improvement according to participant (L), as new nuclear has not really been tried and tested yet but comments that off shore wind puts the UK in an extremely good position and will be a key element in going forward. Participant (R) noted that it does fit the UK energy policy as the coalition government have reiterated support for renewables since the shift in the renewal in administration. Although they are looking at doing something differently, they have reiterated their commitment to supporting the renewable energy sector.

9.5. Theme 5: Rationale behind why the UK is lagging in installed off shore wind capacity

This theme evoked three main sub themes fossil fuel reliance, lack of knowledge and high cost. The lack of knowledge was the main reason concluded by the professionals for the UK's initial lag in up taking offshore wind power. The main areas commented upon under this lack of knowledge were outlined by participant (P) who stated that *"we didn't appreciate the benefits of offshore", "stronger winds" and "easier consent as it not near people's houses"*. Participant (P) further noted that *"we didn't appreciate the scale of wind power which would ultimately be required and that the UK is actually quite crowded"*, which leaves offshore as the only way forward. The aspect of the technology not being suitable was due to off shore winds intermittency and the idea the technology has not been suitable until recently. This was previously concluded by Breton et al. [20] who commented that offshore winds advantages over onshore have only been realised in recent years, as onshore sites become scarce and offshore technology advances.

The high costs associated with offshore technology were discussed by three participants. Participant (E) commented that offshore wind was not as commercially attractive as on shore, with participant (L) commenting that the risks and returns were seen as limited. The difficultly of the offshore environment was an issue highlighted by participant (L) who concluded it vastly increased the associated offshore costs. This gives great weight to the argument suggested by Zhixin et al. [40] who claimed that offshore wind was double or triple the cost of onshore, due to the increased construction complexity and unpredictable marine environment, which made investment in these projects extremely difficult.

9.6. Theme 6: Utilisation of offshore wind power to meet UK 2020 targets

The main reasons identified by the participants in relation to why the offshore wind is being utilised to meet the UK 2020 targets have been fast deployment and decarbonisation. All participants concluded that wind power was the only renewable that could be deployed on a commercial scale. Participant (I) highlighted wind power's importance stating it is *"crucial to the renewable strategy to achieve 20 per cent of our energy resources from renewable energy by 2020"*. The twenty participants further stressed the fact that they believe the majority of that 20 per cent will be from wind power and that if we do not get offshore off the ground we probably won't hit those targets. However participant (D) concluded that wind power will easily meet our 20 per cent target and *"we can expect wind to be producing 25–30 per cent of Britain's energy by 2020"*.

Due to the speed at which offshore wind can be built up, the twenty participants asserted that if we fail to meet our targets in other sectors wind power will be there to take up the slack and due to its flexible nature it will be able to step up to the plate. Bilgili et al. [8] and Mehmet et al. [52] reinforced this theory that wind power is one of the few renewable technologies that can be deployed rapidly, due to the turbines and wind plants being quick to install. The importance of offshore wind to reduce carbon emissions from the electricity generating fleet was briefly mentioned by participant (A) who concluded it was easier to reduce using wind compared to other sector such as heat and transport.

9.7. Theme 7: Rationale behind UK and Merseyside becoming part of the supply chain for off shore wind

The main issue dominating nearly half of the discussion was the fact that they believe the Merseyside (Liverpool, UK) region had been slow to consider the idea of becoming part of the offshore wind supply chain. Participant (C) used the example of Peel Ports, explaining that they had *"only recently come round to realise that offshore wind could be a big money spinner for them when they had previously seen it as a threat to their existing business"*. The other nineteen participants affirmed that Merseyside had been working hard to catch up but now face more competition from Northern Ireland, North Wales and the Isle of Mann. Participant (E) further stressed the benefits of Merseyside's *"close geographical proximity to the Irish Sea Zone"*, with participant (G), (L) and (S) highlighting the Merseyside's huge manufacturing capacity, maritime industries, different levels of port and skill set present in the region.

Under the UK region, participant (A) stressed the fact that although there is the need for large integrated manufacturing companies close to the zone, there are certain non location sensitive items such as turbines and cables and substation components that can be manufactured locally, freighted and shipped around the country. Participant (B) backed up this comment by referring to the 400 multinational businesses the researchers

witnessed, through attending the New Brighton supply chain event, pointing out that there is clearly a massive appetite.

9.8. Theme 8: The barriers the Irish Sea zone and Merseyside region face

A vast range of sub themes arose in relation to the barriers the Merseyside region would face regarding installation of offshore wind. As highlighted by the twenty participants, the three main barriers highlighted were: economic, funding and geographical. Participant (S) stressed that the main constraint with Merseyside's geographic position was the fact that it is in a bay and has various oil, gas, fishing and shipping lanes and even though it is a very large bay it is extremely busy. The economics and funding issues behind offshore wind power was highlighted by participant (H) and (I). Participant (H) highlighted the need to ensure costs are kept low and that these projects remain economic, with participant (I) stressing a problem that until recently offshore has been seen as high risk which made it extremely hard to secure any type of funding support.

Infrastructure issues surrounding problems finding connection access to the national grid were raised by participant (L) and (D). These points tie in with much of the literature which has gone before by Baker [53], Zhixin, et al. [40] and Dolores et al. [32], regarding the need for specialist marine electrical infrastructure to connect with the consumers and the lack of specially constructed vessels for the construction, operation and maintenance of these offshore turbines. Issues with the lack of knowledge regarding the infrastructure planning commission planning process for consenting offshore wind farms and the fact it is going to change was stressed by participant (C). Participant (C) further highlighted the bureaucratic time delays with getting consent from the government, explaining it took the Humber Gateway two years to be granted consent, due to the Department of Energy and Climate Change being overly cautions of granting that. Participants claimed administration services were partly to blame, stating that the government and other consulates such as the Joint National Conservation Committee or Royal Society for the Protection of Birds are not adequately staffed to deal with the number of applications.

9.9. Theme 9: Key drivers for the Irish Sea Zone and Merseyside

The two main drivers identified in relation to offshore wind in the Irish Sea Zone and Merseyside region, were that offshore wind was required to meet the 2020 targets and the benefit that the offshore installations were situated around the UK to spread job and business. The reliance on offshore wind to meet the 2020 targets was a view shared by most participants, with participant (B) claiming offshore wind is *"the key driver in terms of government strategy, government policy and EU policy that we have signed into"*. It is crucial to the future of this country and our EU related targets stated participant (H). From the discussion with the twenty participants, the 2020 target subtheme decarbonisation and security of supply contributed a somewhat balanced argument. Participants affirmed that off shore wind is how the government is going to decarbonise the economy.

The issues of security of supply was summed up by participant (B), who explained that once these projects are up and running after initially taking a lot of capital, you have got 25–30 years where you are not exposed to fuel prices as the wind resource is free. The importance of the architecture of the offshore wind farms was acknowledged by most participants, with participant (A) concluding the geographic spread in terms of round three was important, to spread the jobs and supply chain around the country, so it was not all in one particular location.

9.10. Theme 10: Future of offshore wind in the UK

According to all participants the future of offshore wind power is bright, with huge potential. It is worth highlighting that the majority of the discussion in relation to offshore wind was positive. Participant (T) noted that if the remaining wind power from the Crown Estate is built out and assuming more wind farms are built onshore, we would be close the kind of limit that the grid would except in terms of stability. The twenty participants commented on the massive business potentials and job prospects, with participant (R) concluding that we expect to have around 23 GW by 2020 and beyond that even more. This supports the previous comments by the EWEA [9] and Renewable UK [38], who highlighted the 250,000 jobs expected in this sector with the 6 GW of offshore capacity in consent and 10 GW awaiting planning approval. This reflects the vibrant future of the offshore sector that Freris and Infield (2009) concluded, in the previous literature.

According to participants (Q) and (M) the government remains committed to wind power in the UK. Participant (J) claimed that the government could change its view on wind, when reviewing the renewable obligation, but it is unlikely as many other countries in Europe are following the UK at the moment installing more offshore wind. This is crucial to the future of offshore wind according to participant (A), so developing an infrastructure that can provide this necessity, is crucial to the future of UK energy and offshore wind.

10. Conclusions: the way forward

It is clear that the UK government have developed a huge dependency for electricity over time, which has allowed it to become vitally essential in our daily routine. Industrialisation in the 1750s seen the start of the UK's reliance on fossil fuel sources for electricity generation. Over the past few decades these sources have been slowly dwindling away due to our multiplying population and high demand for these finite sources of energy. This increasing energy demand has led to major issues regarding the global warming of the planet through the combustion of these fuels and issues regarding security of supply, as the majority of these sources are situated in political unstable regions of the world. These issues had long been recognised by the government and have been outlined in numerous reports the most recent being the 2007 White paper on energy and the 2009 Low carbon transition plan.

It was found that there were various global and European frameworks and legislation put in to place to try and combat these issues. However it was clear that they were not having the desired effect in resolving these issues. The EU has set demanding targets for 2020 in relation to reducing carbon emission, energy consumption and increasing renewable technologies for electricity production. Previous research has acknowledged that good progression is being made in relation to meeting these targets, but that could be due to the fact the electricity demand has been reduced due to the recession we are currently witnessing and the use of nuclear and gas for electricity production instead of coal to reduce carbon dioxide emissions, which is not of a renewable source. It was concluded in the primary research that the government focused too heavily on the electricity sector as a means of reducing carbon emissions, instead of focusing on the other areas such as transport, heating and improving energy efficiency.

It was found that the majority of the research concluded that the European Energy targets for 2020 were challenging but were achievable, as the government has been extremely supportive in pushing for these targets. Alternative energy was acknowledged as being vital for the UK in order to meet these 2020 targets, combat

climate change and achieve security of supply through utilising a diverse mix of resources. It was recognised that UK's reliance on imported fossil fuels, reserves in the Irish Sea and the complexity of the planning systems, were the main reasons behind why it had taken the UK so long to utilise the renewable energy technologies, including offshore wind. The issue of the high initial capital intensity surrounding offshore wind and the lack of knowledge in relation to offshore attributes and characteristics were the key reasons behind the UK's delay in utilising offshore wind technologies. It has been identified that these benefits such as stronger winds and the easier planning consent of offshore compared to onshore have not been realised. This meant offshore was not seen as being commercially attractive as onshore, with investors viewing offshore winds as being risky with limited returns.

Offshore wind is now seen as being crucial to achieving these EU targets with the research concluding that offshore wind power will contribute to the majority of the 20 per cent required for renewable electricity generation for 2020. The reasoning behind this is the speed at which offshore wind power can be installed and the fact that offshore wind is one of the few technologies that can be deployed on a commercial scale.

The UK can benefit from a number of features that have significant advantages in the pursuit of offshore wind energy production. Most fundamentally, the UK enjoys access to a vast resource that is relatively easy to connect to well-developed grid systems and main centres of demand. From the findings also, it was made clear that there was potential for the UK region and especially the Merseyside region, to become part of the supply chain for the offshore wind farms planned for the Crown Estates round three offshore wind farms, in particular the Irish Sea Zone, owned by Centrica. The research demonstrated Merseyside (Liverpool, UK) could successfully contribute quite heavily to the Irish Sea Zone, with its huge manufacturing capacity, maritime industries, skill set present in the region. It was argued however that Merseyside has been slow to acknowledge these opportunities and would have to fight hard to catch up and compete for contracts in this area.

The geographic proximity of Merseyside to the Irish Sea was initially seen as an advantage but the fact that the Merseyside region is located in a busy bay, evoked problems with shipping lanes and infrastructure surrounding connecting to the grid.

Elsewhere in the UK it was concluded that there were opportunities on existing rounds as well as other round three zones for the non-location of sensitive items to be manufactured within the UK which could be transported to the required zones. The more general barriers highlighted in relation to offshore wind were, the lack of knowledge surrounding the current infrastructure planning commission planning process for consenting offshore wind; with the suggestion that it is due to change again and the fact that many of the consulates for offshore wind are not adequately staffed to deal with the number of offshore applications. However all the literature and primary research concluded that the future of offshore wind was extremely bright, with 250,000 job prospects forecasted in this sector by the EWEA [9] and Renewable UK [38] in relation to the 6 GW of offshore capacity in consent and 10 GW awaiting planning approval. It was however highlighted that for offshore to flourish in the future, the UK needed to update and increase the stability of the current grid infrastructure to handle the increasing renewable technologies and allow electricity to be traded to Europe and beyond.

It is worth highlighting that the burgeoning offshore wind industry is set to become a major manufacturing activity in the UK, bringing significant new inward investment, businesses and jobs. To help make sure this industry realises its full potential, the Government needs to take a proactive approach. As shown in this study, offshore wind will play a crucial role in the UK government's commitment for renewable energy. From the reviewed literature and primary findings, there is a growing realisation of the scale of challenge energy operator's face in the UK energy market. These include: energy affordability, energy security and the tackling of climate change. The industry and the Government need to work hard to drive down the cost of producing electricity from offshore wind energy.

This research has elicited many questions in need for further investigation. A further avenue of investigation evoked from the primary research is the issue of the government continuously targeting the electricity sector as a means of reducing carbon emission instead of focusing on the other areas such as transport, heating and improving energy efficiency. It would be interesting to investigate why the government is not focusing on the other areas such as heating transport and improving energy efficiency as a mean of reducing carbon emissions, instead of focusing solely on the electricity sector. Other areas that could be investigated could be the skills and trades available to the UK regions that could become part of the supply chain for these projects, in order to identify if further training is required nationally to satisfy the job criteria in the wind sector.

Appendix A. Interview Questions

Future for Offshore Wind Energy in the United Kingdom: The way forward

Please note: All information provided will be treated as confidential.

General Energy Related Questions

1. What is your opinion on the importance of alternative methods of generating electricity?
2. Why do you think it has taken so long for the UK to move towards the alternative energy sector?
3. What are your thoughts on the current energy policies that have been set out by the government? Do you think they are achievable?
4. Do you believe that alternative energy fits into the energy policy of the UK?

Off Shore Wind Related Questions

1. Why do you think it has taken so long for the UK to utilise this source of alternative energy?
2. How do you think wind power fits into the UK's alternative sources of energy?
3. Do you think the Merseyside region has what it takes to become part of the supply chain for the off shore wind farms planned for the Irish Sea Zone?
4. What are the current barriers that off shore wind farms in the Irish Sea and Merseyside region are facing?
5. What are the main drivers for these projects in the Irish Sea and Merseyside region?
6. What are your thoughts on the future of offshore wind farms in the UK?

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